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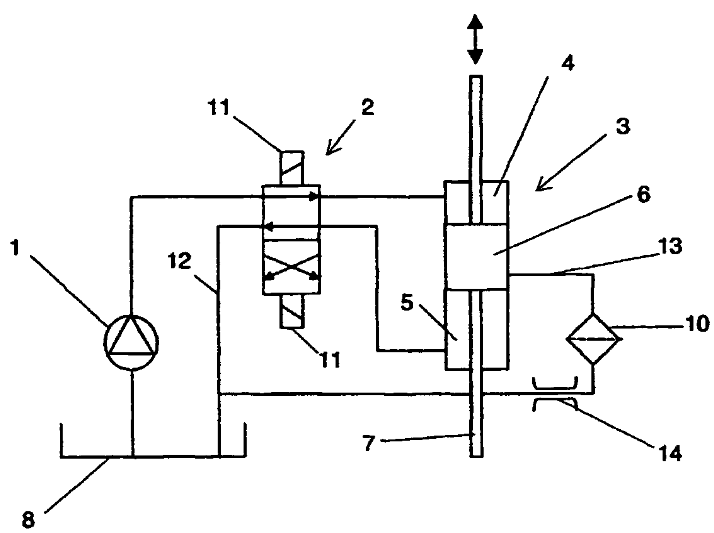
(54) Title: APPARATUS FOR CONTROLLING AT LEAST ONE ENGINE VALVE IN A COMBUSTION ENGINE



(57) Abstract: The present invention relates to an arrangement for controlling at least one engine valve (25) of a combustion engine. The arrangement incorporates a hydraulic circuit with a pump (1), a control valve (2) which is designed to control a flow of medium in the circuit, and a power device (3) which is designed to move the engine valve (25) between open and closed positions. The pump (1) is designed to circulate a flow of medium continuously in at least part of the circuit during an operating state of the combustion engine, and the control valve (2) is designed to direct as necessary the flow of medium circulated by the pump (1) to the power device (3) so that the latter moves the motor valve (25) in a desired direction.

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Apparatus for controlling at least ne engine valve in a c mbustion engine

STANDPOINT OF THE INVENTION, AND STATE OF THE ART

The present invention relates to an arrangement for controlling at least one engine valve of a combustion engine according to the characterising part of patent claim 1.

Engine valve here means an inlet valve or exhaust valve for a combustion chamber of a combustion engine.

The movements of such engine valves are traditionally controlled by a camshaft by means of cams whose profile controls those movements, the camshaft being driven via a transmission by the engine's crankshaft. With such traditional control, many parameters which are related to the engine valves are not variable relative to one another. For example, the opening and closing times of the engine valves cannot be varied with the engine speed. An engine can therefore not be caused to achieve optimum operation throughout its speed range.

A number of mechanical systems have been developed for achieving a more flexible control of engine valves. Such systems are operationally reliable and relatively uncomplicated but do not result in fully variable control of engine valve lifting heights and opening and closing times.

Electrical systems for control of engine valves have also been developed. In such cases, engine valve movements are controlled by electromagnets. Such systems can control engine valve opening and closing times variably, but partial lifting of engine valves is difficult to achieve. It is also difficult for electromagnets to exert sufficient force to effect valve lifting when the gas pressure in the combustion chamber is high.

Finally, hydraulic control systems for engine valves are known. Hydraulic systems make it possible to vary engine valve opening and closing times and lifting heights. The known hydraulic systems operate at a substantially constant high pressure. A hydraulic pump and a pressure limiting valve are used to impart this high pressure to a hydraulic fluid

which is stored in an accumulator. When an engine valve is intended to be moved to an open or closed position, a control valve is switched so that the pressurised hydraulic fluid is led into a circuit to a hydraulic cylinder in which the hydraulic fluid moves the piston. The problem with such systems is that they require a substantially constant high pressure which itself means that such a system involves a relatively high energy consumption. The high pressure and the need for the system to be completely tight entail severe requirements for the seals which form part of the system.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an engine valve control arrangement which makes it possible for the engine valve opening and closing configuration to be substantially completely variable and which at the same time entails low energy consumption and does not require expensive seals.

This object is achieved with the arrangement mentioned in the introduction, which is characterised by the pump being designed to circulate a flow of medium continuously in at least part of the circuit during an operating state of the combustion engine, and by the control valve being designed to control according to need the flow of medium circulated by the pump to the power device so that the latter moves the engine valve in a desired direction. The advantage of having a continuously circulating medium flow is that the medium already has a certain velocity in the circuit. Rapid movement of the engine valve in a desired direction is achieved by directing such a medium already circulating to the power device. The pressure drop in the circuit can be kept at a low level by providing the hydraulic circuit with large flow cross-sections. The pump therefore requires relatively little energy for it to circulate the medium continuously in the circuit. As a high pressure is only required for the short periods of time when the engine valves are accelerated by the medium, the arrangement may be constructed entirely or substantially entirely without seals. In addition, components incorporated in the circuit may be manufactured with relatively large tolerances. The possible advantages include the arrangement being relatively insensitive to thermal variations and insensitive to any contaminants in the oil.

According to a preferred embodiment of the present invention, the control valve has at least two possible positions, whereby a first position results in the medium flow being led so that the power device moves the engine valve in a first direction, and a second position results in the power device moving the engine valve in a second direction. For such a control valve to function properly, it needs to be movable quickly between said two positions. The components incorporated in the circuit therefore need relatively large flow cross-sections so that a large quantity of medium can reach the power device without considerable constriction losses. With advantage, the power device incorporates a double-acting hydraulic cylinder with an internal space divided into first and second chambers by a piston which is movable within the chamber and which is connected to the engine valve, whereby the control valve in the first position is intended to lead the circulating medium to the first chamber, and in the second position to lead the circulating medium to the second chamber. The circulating medium may thus alternately be led by means of the control valve to the first and second chambers of the hydraulic cylinder in order to move in a desired direction the piston and hence the engine valve connected to the piston.

According to another preferred embodiment of the present invention, the control valve has a third possible position whereby the medium flow is intended to be directed so that it does not reach the power device. Switching the control valve from its first or second position to said third position prevents the medium reaching the first and second chambers. Movement of the piston and of the engine valve is thus halted. Preferably, the control valve in said third position also bars any flow to and from said first and second chambers. The piston and the engine valve are thus forcibly kept in their existing positions. Such switching to the third position may take place automatically when the engine valve has assumed a fully open or closed state. Alternatively, such switching may also take place when so-called partial lifting is desired, i.e. when it is not desired that the valve opens fully.

According to another preferred embodiment of the present invention, an outlet line is arranged in the cylinder and the medium flowing into the respective chamber is allowed to pass out via said outlet line when the piston has moved to a specific position in said chamber. Using such an outlet line means that the control valve requires only two

positions for controlling the engine valve, thereby making it possible for the control valve to be provided with a short travel between the two positions. This may be an advantage, since the control valve has to be able to switch quickly in order, within a short space of time, to free large flow cross-sections. Such an outlet automatically establishes a circulating medium flow when the piston reaches an end position. With advantage, said outlet incorporates a throttle valve. Such a throttle valve provides the medium with a specific pressure in the outlet line. The pressure of the medium in the respective chamber in the cylinder thus becomes equal to that pressure. This medium pressure acts upon the piston so as to keep the engine valve in an open or closed position. Such a throttle valve may be settable so that the pressure in the outlet line can be varied.

According to a preferred embodiment of the present invention, the cylinder incorporates means intended to damp the piston's movement in the cylinder when, or immediately before, it reaches an end position corresponding to a fully closed or open engine valve. As the piston requires a high velocity for switching the engine valve quickly, the piston requires damping at its end positions to prevent its being subject to excessive stresses. Said damping means may include at least part of the piston being provided with a cross-sectional area which decreases towards the end of the piston and is designed to be accommodated in a recess. The steadily decreasing cross-sectional area of the piston being led into a recess results in the medium enclosed in the recess by the end of the piston passing out through an aperture with a steadily decreasing cross-sectional area. In this way the piston can be provided with damping as it reaches its end position.

According to another preferred embodiment of the present invention, the control valve is designed to be controlled by electrical signals from a control unit. The control valve may incorporate solenoids which switch the control valve to a desired position according to electrical signals received from the control unit. The control unit emitting electrical signals may be a computer unit which uses information on the respective combustion engine to control the movements of the engine valves so as to achieve as close as possible to optimum operation of the engine on the basis of various operating parameters for the engine. Examples of how the engine can be controlled include facilities for exhaust braking, for alternate operation as a two-stroke or four-stroke engine, for using so-called internal EGR (whereby exhaust gases are intended to be retained in the cylinder before

the next induction stroke) and for optimised operation with regard to economy or power requirements.

According to another preferred embodiment of the present invention, a retaining device is designed to keep the engine valve forcibly in a desired position. In cases where the circulating medium does not provide sufficient force to keep the engine valve in a closed position, such a retaining device can supply supplementary force as necessary. Such a retaining device may incorporate an electromagnet.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below by way of examples with reference to the attached drawings, in which:

Fig.1a-c	depicts a first embodiment of the present invention with a control valve in various positions.
Fig.2	depicts schematically a second embodiment of the present invention,
Fig.3a-d	depicts in more detail how the arrangement in Fig.2 may be implemented.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

The embodiment described below relates to a combustion engine, such as a multi-cylinder diesel engine of piston and cylinder type for use as drive engine in a heavy-duty vehicle such as a truck or a bus. As all the engine cylinders are of similar configuration, the configuration of only one of them will be described, which also means that the invention can be used in a single-cylinder engine.

Fig.1a-c depicts a first embodiment of a hydraulic circuit designed to control an engine valve between at least an open position and a closed position. The hydraulic circuit incorporates a pump 1 which is designed to pump a substantially constant volume of a medium, preferably oil, in the circuit. The circuit also incorporates a control valve 2 which may be placed as necessary in three different positions. The control valve 2 may therefore lead the medium in three different directions in the circuit in order to control the

movements of a double-acting hydraulic cylinder 3. The hydraulic cylinder 3 contains an internal space divided into a first chamber 4 and a second chamber 5 by a piston 6 which is movable in the chamber. The piston 6 is connected by a piston rod 7 to an engine valve which is not depicted in Fig.1a-c. The engine valve is movable by means of the hydraulic cylinder 3 between an open position and a closed position. Such an engine valve is arranged adjacent to a combustion chamber of the combustion engine. The engine valve may be an inlet valve designed to control the entry of air or a fuel/air mixture into the combustion chamber. Alternatively, the engine valve may be an exhaust valve designed to control the departure from the combustion chamber of the exhaust gases formed during the combustion process. The circuit also incorporates a medium reservoir 8 in which the medium is stored. Also arranged in the circuit are a pressure limiting valve 9 and a filter 10. The sole function of the pressure limiting valve 9 is to act as a safety valve to prevent excessive pressure occurring in the circuit as a result of any possible fault, so the pressure limiting valve 9 has no direct function in normal operation.

Fig.1a shows the control valve 2 in a first position. The control valve 2 incorporates two solenoids 11 designed to move the control valves to a desired position. The solenoids 11 receive control signals from a control unit which is designed to control the engine valves so that the combustion engine achieves as close as possible to optimum operation. In this situation the medium is led from the pump 1 in the circuit through the control valve 2 to the first chamber 4 of the hydraulic cylinder 3. At the same time, the control valve 2 connects the second chamber 5 of the hydraulic cylinder 3 to the medium reservoir 8. Medium is thus allowed to flow out from the second chamber 5, via a return line 12, back to the medium reservoir 8 while at the same time medium flows into the first chamber 4. The medium inflow thus moves the piston 6 downwards in a first direction. As the piston rod 7 is connected to the engine valve, the latter also moves. The engine valve may thus be moved, for example, from a closed to an open position.

Fig.1b shows the control valve 2 in a second position. In this second position, the medium flow is led from the pump 1 via the control valve 2 to the second chamber 5 of the hydraulic cylinder 3. At the same time, the first chamber 4 is connected to the return line 12 so that the medium in the first chamber 3 is led back to the medium reservoir 8. The medium flow thus moves the piston 6 upwards in Fig.2b. This results in the piston

rod 7 connected to the piston 6 moving the engine valve in an opposite direction to that in Fig.1a. The engine valve is thus moved, for example, from a fully open to a closed position.

Fig.1c shows the control valve in a third position. The control valve 2 preferably assumes this third position automatically when the piston 6 has reached in the hydraulic cylinder 3 an end position corresponding to a fully closed or open engine valve. The control valve 2 may also assume this third position when so-called partial lifting is desired instead of full opening of an engine valve. When the piston 6 has reached such a position, the control valve 2 prevents further medium flow to the two chambers 4,5. At the same time, the control valve 2 retains the medium which is already in the first chamber 4 and second chamber 5. Both the piston 6 and the engine valve are thus kept forcibly in their existing positions. In the third position of the control valve, the medium is led back from the pump 1 to the medium reservoir 8 via the control valve 2 and the return line 12. Even if the piston 6 does not perform any movement, a substantially constant medium flow is thus pumped continuously in the circuit by the pump 1.

When it is desired that the engine valve should move from the position in Fig.1c, an electrical control signal is led from the control unit to the solenoids 11. The solenoids 11 switch the control valve 2 to the first or second position as desired. The circulating medium, which already has a velocity in the circuit, is thus led quickly to the respective chamber 4,5 so that the desired movement of the engine valve can be achieved at a high velocity. It is advantageous to use a pump 1 which has a fixed displacement and is coupled to a crankshaft of the engine. The engine valve can thus be provided with a switching velocity proportional to the engine speed. As the pressure in the circuit is only high for the brief periods of time which correspond to the acceleration movement of the piston 6, the circuit may incorporate relatively large tolerances without entailing excessive leakage. Seals may therefore be dispensed with. The possibility of having relatively large tolerances reduces the purity requirements for the medium. This makes it possible, for example, to use motor oil as the medium, and for the medium reservoir 8 to take the form of an existing oil sump.

Fig.2 depicts schematically another embodiment of the arrangement. In this case a pump 1 leads a flow of medium to a control valve 2 which has two possible positions. After passing through the control valve 2, the medium may alternatively be led to a first chamber 4 or a second chamber 5. At the same time, the chamber 4,5 which is not supplied with the medium is connected to a return line 12 which leads the medium back to the medium reservoir 8. Moving the control valve 2 to the first or second position results in movement of a piston 6 which separates said chambers 4,5. The piston 6 is provided with a piston rod 7 which is connected to an engine valve not depicted in Fig.2. The hydraulic cylinder 3 also incorporates an outlet line 13. The outlet line 13 is positioned so as to be alternatively connected to the first chamber 4 or the second chamber 5 immediately before the piston 6 in the cylinder 3 reaches an end position which corresponds respectively to a fully closed or open engine valve. When the respective chamber 4,5 is connected to the outlet line 13, the medium flows out of that chamber 4,5 via the outlet line 13. Such an outlet line 13 reduces the pressure of the medium on the piston 6 immediately before the latter reaches its end position. The velocity of the piston 6 is thus decelerated. The outlet line 13 incorporates a throttle valve 14 designed to maintain a desired pressure of medium in the outlet line 13. This also results in a corresponding pressure in the respective chamber 4,5. The force which holds the piston 6 and the engine valve in a closed or open position can therefore be regulated by the throttle valve. When the piston 6 has reached an end position and comes to a halt, the pump 1 thus continues to circulate the medium in the circuit. In this situation the medium passes through the first chamber 4 or second chamber 5 of the hydraulic cylinder 3 and through the outlet line 13 to the medium reservoir 8 via the filter 10 and the throttle valve. When engine valve movement in an opposite direction is desired, the control unit sends an electrical control signal to the solenoids 11, which switch the control valve 2. Circulating medium is thus led from the pump 1 via the control valve 2 to the respective chamber 4,5. This medium flow causes the piston 6 and hence the engine valve to move in a desired direction.

Fig.3a-d shows in more detail a possible configuration of the arrangement in Fig.2. A pump 1 circulates a medium from a medium reservoir 8 to a control valve 2 which can be moved to first and second positions. The control valve 2 contains an internal space delineated by a first piston 15, a second piston 16 and a third piston 17. These three

pistons 15,16,17 are firmly connected to a movable piston rod 18. The medium has two alternative inlets 2 and three outlets from the control valve 2. A first outlet incorporates a first line 19 connected to a first chamber 4 of the hydraulic cylinder 3. A second outlet incorporates a second line 20 connected to a second chamber 5 of the hydraulic cylinder 3. A third outlet incorporates a third line 12 which leads the medium back to the medium reservoir 8. The hydraulic cylinder 3 incorporates a piston 6 which comprises an upper piston portion 21 and a lower piston portion 22. The upper and lower piston portions 21 and 22 respectively exhibit cross-sectional areas which decrease towards the end surfaces of the piston 6. The hydraulic cylinder 3 incorporates an upper recess 23 and a lower recess 24 which are respectively designed to accommodate said upper and lower piston portions 21 and 22. The piston 6 incorporates a piston rod 7, the lower end of which is connected to an engine valve 25. The hydraulic cylinder 3 incorporates an outlet line 13 with a throttle valve 14.

Fig.3a shows the lines carrying the medium flow in the circuit shaded, with a fully closed engine valve and a control valve 2 in a second position. In this case the medium is led from the medium reservoir 8 by means of the pump 1 via the lower inlet to a lower chamber 26 in the control valve 2. The upper piston 15 prevents the medium from being led into an upper chamber 27 of the control valve 2. After passing through the lower chamber 26, the medium is led through the second line 20 to the second chamber 5 of the hydraulic cylinder 3. In this situation the piston 6 is in its upper end position. The second chamber 5 is therefore connected to the outlet line 13. The medium flowing into the chamber 5 passes on out through the outlet line 13, via the throttle valve 14, back to the medium reservoir 8. The pressure of the medium in the outlet line 13 is determined by the throttle valve 14. The same pressure prevails in the second chamber 5 and also determines the force which keeps the engine valve 25 in a closed position.

In Fig.3b the control valve 2 has moved to a first position. The circulating medium is led, as illustrated by the shading, from the pump 1 to the upper chamber 27 in the control valve 2. The piston 17 prevents the medium from being led into the lower chamber 26. From the upper chamber 27, the medium passes through the first line 19 to the first chamber 4 of the hydraulic cylinder 3. The medium flowing into the first chamber 4 pushes the piston 6 downwards and hence also moves the valve 25 from a closed to an

open position. The control valve 2 in this first position allows the medium in the second chamber 5 of the hydraulic cylinder 3 to be led back through the second line 20 via the lower space 26 in the control valve 2 to the return line 12 and the medium reservoir 8. This medium flow is illustrated by the dotted portions of Fig.3b.

In Fig.3c the engine valve 25 has reached its fully open position. The medium in the first chamber 4 of the hydraulic cylinder 3 has now been connected to the outlet line 13. The medium flowing to the chamber 3 is led through the outlet line 13 and the throttle valve 14 back to the medium reservoir 8. The connection to the outlet line 13 opened substantially immediately before the piston 6 reached its lower end position. The medium being allowed to pass through the outlet line 13 has reduced the pressure of medium on the piston 6. The velocity of the piston 6 was therefore decelerated before it reached its lower end position. The piston 6 exhibits a lower piston portion 22 with cross-sectional area which decreases towards the end of the piston. The lower piston portion 22 is designed to be accommodated in a lower recess 24 in the cylinder 3 before the piston reaches said end position. The medium which is in the recess 24 will therefore be forced upwards and will pass through a gap with a steadily decreasing cross-section. The velocity of the piston 6 is thus also damped in this way before the piston 6 reaches its end position with an engine valve in a fully open position.

In Fig.3d the control valve 2 has reverted to its second position. The medium is led back from the pump 2 to the lower space 26 of the control valve 2. Thereafter the medium is led through the second line 20 to the second space 5 of the hydraulic cylinder 3. At the same time, the control valve 2 allows the medium in the first chamber 3 (dotted areas) to pass via the first line 19 and the upper space 27 of the control valve 2 to the return line 12 and the medium reservoir 8. In this situation the engine valve 25 has moved towards a closed position of the piston 6. When the engine valve 25 has reached a fully closed position, the process can continue as depicted in Fig.3a.

The present invention is in no way limited to the embodiments depicted in the drawings but may be varied freely within the scopes of the patent claims.

Patent claims

1. Arrangement for controlling at least one engine valve (25) of a combustion engine, which arrangement incorporates a hydraulic circuit with a pump (1), a control valve (2) which is designed to control a flow of medium in the circuit, and a power device (3) which is designed to move the engine valve (25) between an open position and a closed position, characterised in that the pump (1) is designed to circulate a flow of medium continuously in at least part of the circuit during an operating state of the combustion engine, and that the control valve (2) is designed to control as necessary the flow of medium circulated by the pump to the power device (3) so that the latter moves the engine valve (25) in a desired direction.

2. Arrangement according to claim 1, characterised in that the control valve (2) has at least two possible positions, namely a first position which leads a flow of medium so that the power device (3) moves the engine valve (25) in a first direction, and a second position such that the power device (3) moves the engine valve (25) in a second direction.

3. Arrangement according to claim 2, characterised in that the power device incorporates a double-acting hydraulic cylinder (3) with an internal space divided into a first chamber (4) and a second chamber (5) by a piston (6) which is movable in the space and which is connected to the engine valve (25), whereby the control valve (2) in the first position is designed to lead the circulating medium to the first chamber (4), and in the second position to lead the circulating medium to the second chamber (5).

4. Arrangement according to claim 2 or 3, characterised in that the control valve (2) has a third possible position whereby the flow of medium is intended to be directed so that it does not reach the power device (3).

5. Arrangement according to claim 3, characterised in that an outlet line (13) is arranged in the cylinder (3) so that the medium flowing into the respective chamber (4,5) is allowed to pass out through said outlet line (13) when the piston (6) has moved to a specific position in said space.

6. Arrangement according to claim 5, characterised in that said outlet line (13) incorporates a settable throttle valve (14).

7. Arrangement according to claim 3, characterised in that the cylinder (3) incorporates means designed to damp the movement of the piston (6) in the cylinder (3) when or immediately before it reaches an end position which corresponds to a fully closed or open engine valve (25).

8. Arrangement according to claim 7, characterised in that said means involve at least part of the piston (6) exhibiting a cross-sectional area (21,22) which decreases towards the end of the piston and which is designed to be accommodated in a recess (23,24).

9. Arrangement according to any one of the foregoing claims, characterised in that the control valve (2) is designed to be controlled by electrical signals from a control unit.

10. Arrangement according to any one of the foregoing claims, characterised in that a retaining device is intended to keep the engine valve (25) forcibly in a closed position.

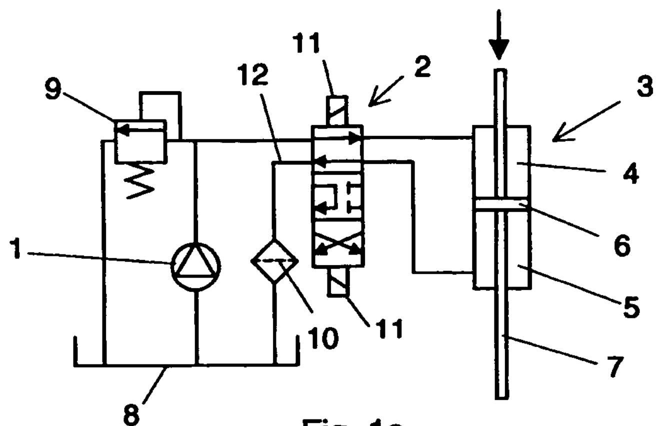

Fig 1a

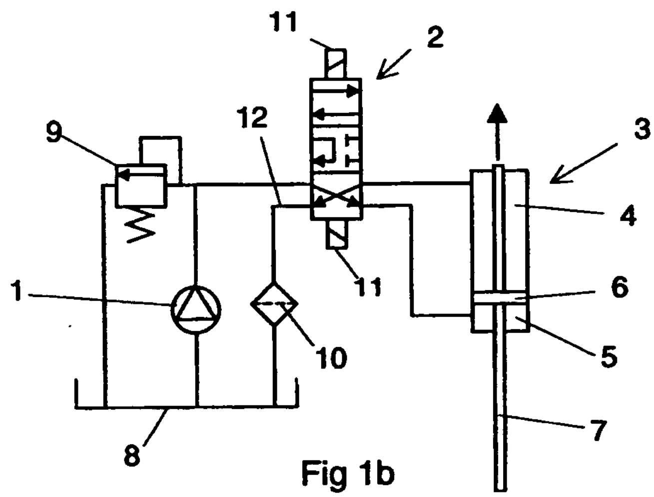

Fig 1b

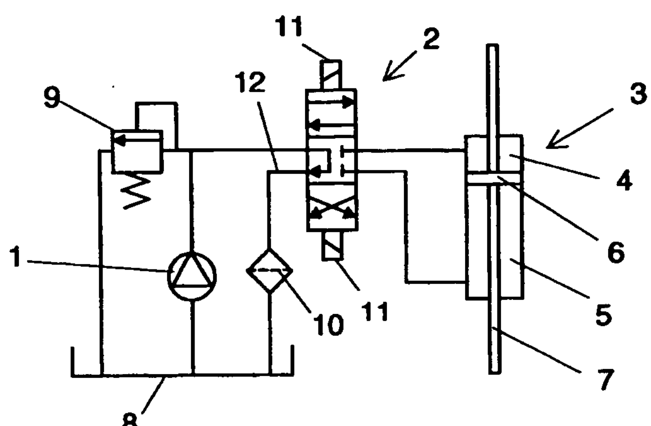

Fig 1c

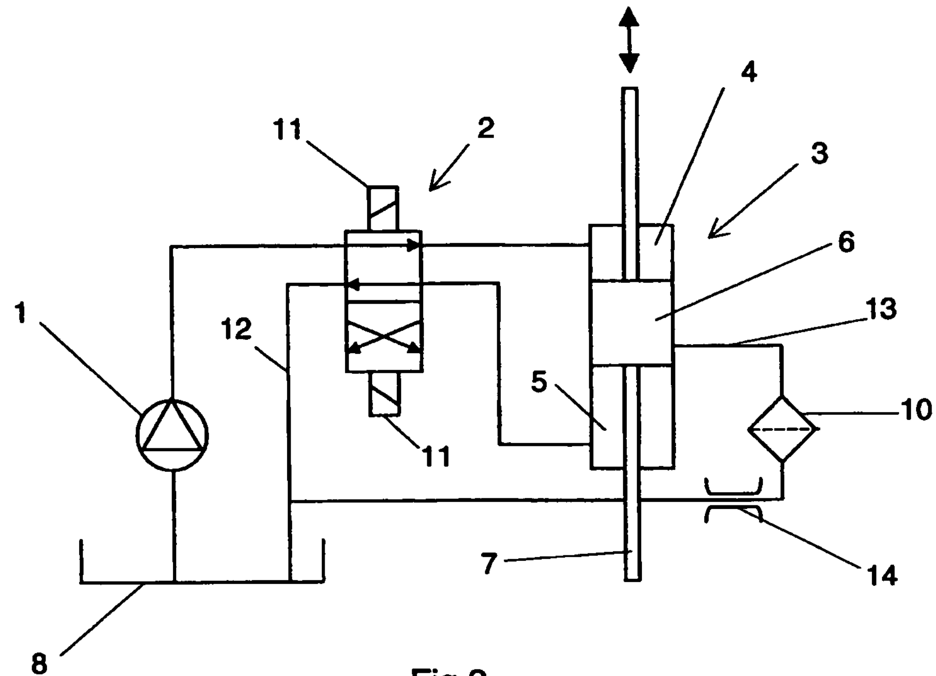
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Fig 2

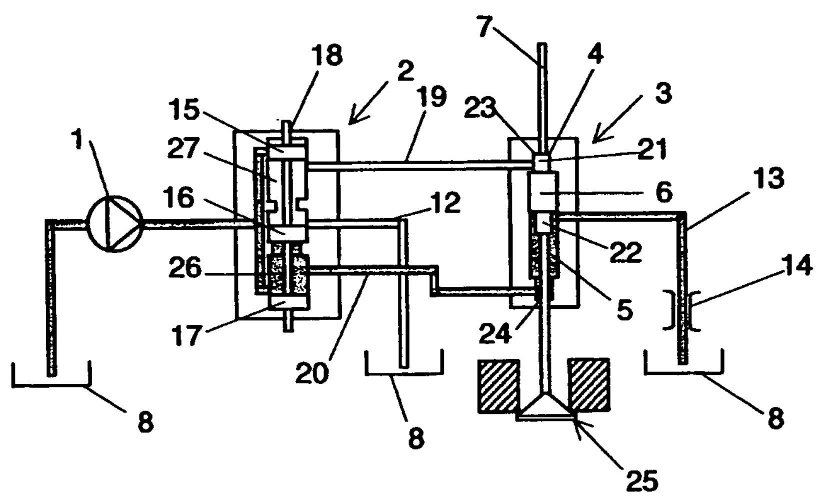
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Fig 3a

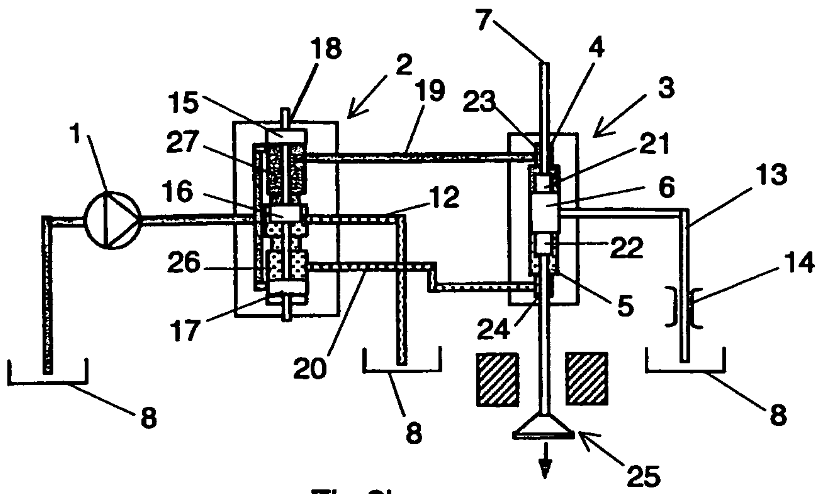

Fig 3b

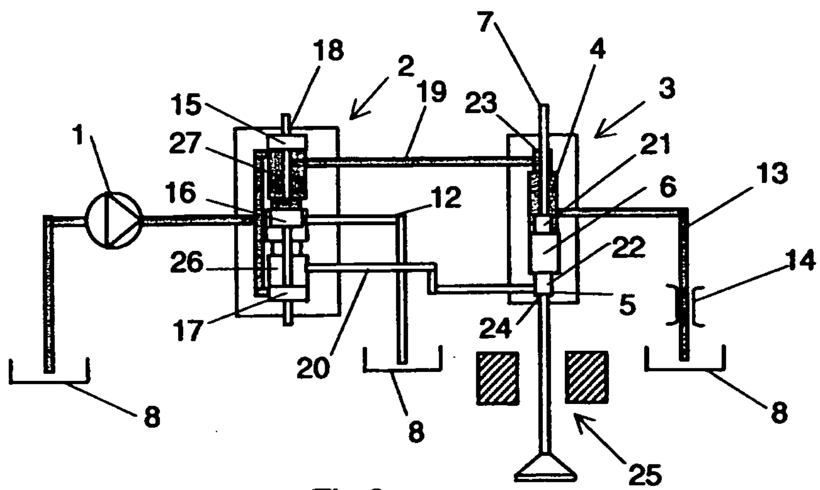

Fig 3c

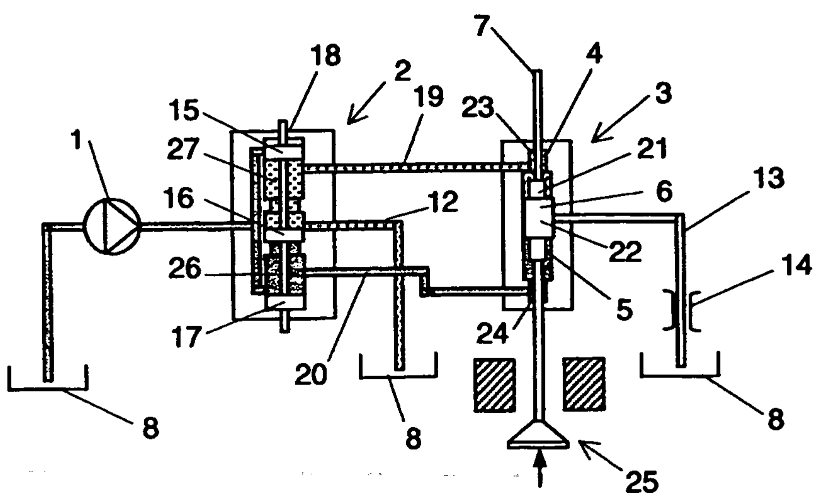

Fig 3d

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01778

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F01L 9/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2224312 A (DAIMLER BENZ AKTIENGESELLSCHAFT), 2 May 1990 (02.05.90)	1-3
A		4-10
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A	SE 301566 (MISUBISHI SHIPBUILDING & ENGINEERING CO., LTD.), 10 June 1968 (10.06.68)	1-10
	--	
A	SE 399739 (ROBERT BOSCH GMBH), 23 August 1973 (23.08.73)	1-10
	--	
A	DE 2008668 (ROBERT BOSCH GMBH), 9 Sept 1971 (09.09.71)	1-10
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
13 December 2000	20 -12- 2000
Name and mailing address of the ISA/ Swedish Patent Office B x 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Per-Olof Warnbo/mj Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01778

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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